Center for Satellite and Hybrid Communication Networks

High Data Rate Satellite Networks and Communication Support for NASA Missions

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Industry Interest: TRW, Space Systems Loral, Hughes Space & Comms, Loral Skynet, Boeing, Teledesic, Orbital Sciences, COMSAT Labs.

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Research on Broadband Satellite Networks: Objectives and Significance for Industry

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- **Objectives:**
  - Assist in system design optimization of broadband satellite networks.
  - Investigate/Facilitate interoperability with terrestrial networks.
  - Conduct performance comparisons of candidate technologies for waveform selection, signaling techniques, on-board processing, dynamic bandwidth allocation, routing and hand-off, network management.
  - Develop and apply tools for fast performance evaluation to specific broadband satellite systems.
  - Investigate QoS provision for Internet access, multimedia services and specialized applications (e.g. Telemedicine) via satellite.
- **Significance:**
  - Satellite resources are very expensive; Detailed and dynamic system optimization is therefore necessary to enable commercial satellite systems to offer competitive prices with other competing technologies.
  - Broadband satellite networks will play a major role in the provision of GII/NII, however there is a need to overcome some of the shortcomings inherent in satellite-based systems to ensure QoS provision and transparent interoperability with terrestrial networks.

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Support for NASA Missions: Objectives and Significance for NASA

- **Objectives:**
  - Provide high quality broadband communications connectivity to the ISS from commercial satellite networks
  - Facilitate broadband Internet services throughout NASA missions
  - Provide performance evaluation of space communication systems

- **Significance:**
  - International Space Station (ISS) is the NASA Mission with the highest priority
  - National Space Policy mandate for NASA to commercialize its space communications operations
  - Reduction in cost for NASA broadband communication needs
  - Better and easier dissemination of NASA mission and experiments data

Support for NASA Missions: Objectives and Significance for Industry

- **Objectives:**
  - Efficient and cost effective communications from spacecraft to commercial satellite constellations
  - Every spacecraft and instrument as an IP address
  - Bring commercial communication services to commercial space
- **Significance :**
  - Commercial Space needs high data rate and high quality communications
    - Experiments with ISS
    - Spacecraft linkage
    - Future space habitats and planetary missions
  - NASA and commercial space are large customers (markets) for commercial communication companies

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Background

- **CSHCN can play a unique role in research studies into issues related with:**

  (a) performance optimization of commercial broadband satellite networks

  (b) supporting communications from the ISS (and other NASA missions) using commercial satellite constellations

  – Significant research accomplishments in recent years (basic research & industry collaboration) in design & optimization of broadband satellite networks

  – Development of:

    - **Analytical Tools**
    - **Simulation Testbed**
    - **Hybrid Networks Laboratory/Hardware Testbed**

  used in studies of satellite systems which can be easily adapted to fit various studies in this area.

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Recent CSHCN Accomplishments

- Development of optimal and near-optimal policies for dynamic bandwidth allocation for multimedia traffic in TDMA and CDMA broadband satellite systems
- Design & trade-off analysis for an on-board switch for a HDR Satellite System
- Investigation into use of Global Processor Sharing / Fair queueing techniques to ensure Bandwidth Control & QoS Guarantees to multimedia service transmission via satellite
- Performance evaluation of hand-off algorithms for a MEO satellite system with diversity

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Recent CSHCN Accomplishments

- Research work in: waveform selection;
  signaling techniques;
  coding & link enhancement
- Development of integrated network management systems for broadband satellite networks
- Development of intelligent monitoring and fault management systems for large satellite networks
- Development of tools for fast performance evaluation of large HDR satellite systems and networks.

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Development of Analytical Tools

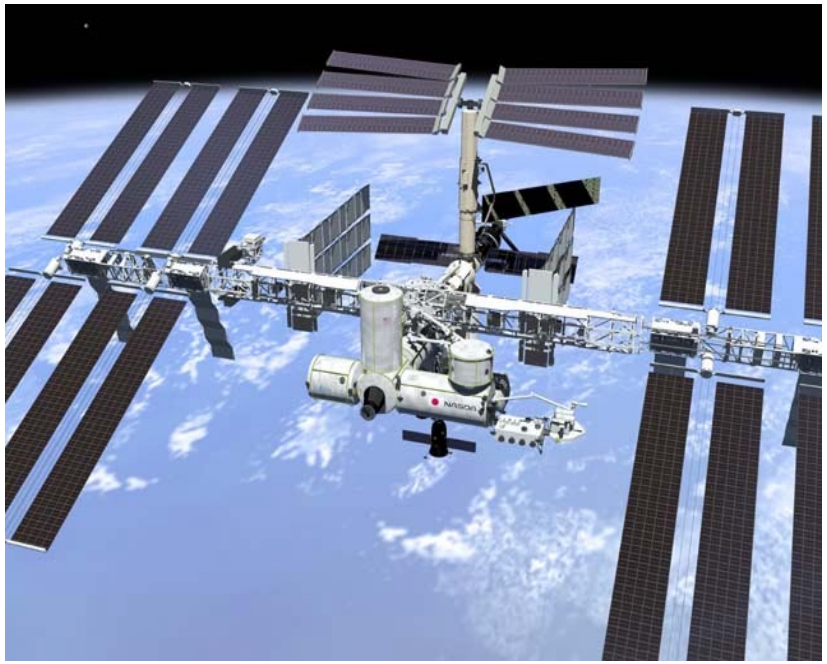
- **Traffic source models (VBR, Internet), specifically adapted for fast end-to-end performance evaluation in satellite & hybrid networks**
- **Analytical tool for fast evaluation of On-Board Switching Schemes**
- **Analytical tool for fast evaluation of end-to-end performance measures (delay, blocking) for multihop networks**
- **Planning tool for satellite/terrestrial networks**
  - Inputs: Demographics, demand, geography, network elements, network models
  - Outputs: Trade-off between heterogeneous network mixed architectures, selection of best trade-off

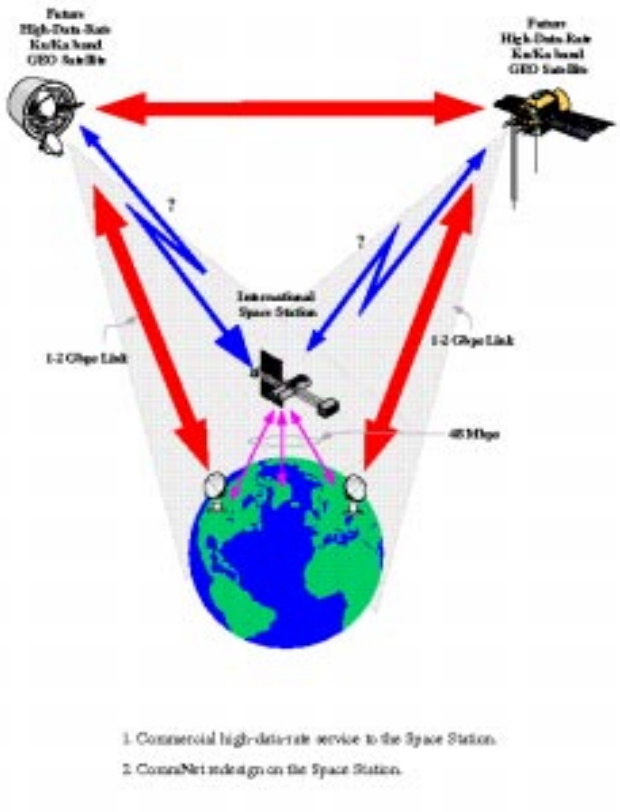
Development of Simulation Testbed

- **Modular simulation testbed under development includes:**
  - Realistic traffic source models for broadband services
  - Protocol enhancements for Internet (TCP/IP) and ATM service provision via satellite
  - Orbital/coverage models of candidate satellite constellations
  - Satellite Gateway Model (Link Enhancements (Coding), Framing)
- **Further enhancements will include:**
  - Network topology architectures (including Inter Satellite Links)
  - Antenna & channel RF (Ka and V Band cases) characteristics
  - On-board switching models
  - Phase arrays and tracking

High Data Rate Communications for the ISS and NASA missions

- **OBJECTIVE:** Investigate the use of commercial GEO and LEO/MEO satellite constellations for the communication needs of various NASA missions and in par
  Station (ISS).





Special Session at Conference on International Space Station Utilization

- On February 2, 1999 CSHCN organized Special Session at Conference on International Space Station Utilization

Commercial Communication System for the ISS

Papers:

- **Dr. Thomas Brackey *et al.*** (Hughes Space and Communications)
  Title: *Commercial Communications for the ISS: System Considerations*
- **Dr. Joseph Bravman *et al.*** (Orbital Sciences)
  Title: *The Application of a Commercial Wideband Constellation for ISS Communications*
- **Dr. Carl Mitchell *et al.*** (Space Systems Loral)
  Title: *Adjunct Payload for ISS High-Data-Rate Communications*
- **Mr. Marty Skudlarek *et al.*** (Lockheed Martin)
  Title: *ISS Migration to Commercial Standards Wideband Data Link*

Communication Support for the ISS - Project Plan

- **Phase I:**
  1. Determine, in cooperation with NASA LeRC particular traffic scenarios, QoS service requirements for initial analysis scenario
  2. Identify potential commercial systems as candidate for investigation, starting from simple GEO (existing) Ku/Ka-band systems and moving to Ka/V band MEO / LEO systems
- **Phase II:**
  1. Where necessary apply analytical tools for traffic modeling, handoff analysis, fast end-to-end performance evaluation
  2. Develop simulation model that includes network architecture & topology of Hybrid Network, including:
     - **ISS (treated as an extremely LEO satellite) & NASA ground network.**
     - **Candidate Commercial Systems (constellation orbit model, ground network topology, information on routing options through constellation, ISLs if any)**
- **Phase III:**
  - Using analysis & simulation perform detailed studies to quantify the performance of candidate satellite systems for specific services, protocols & traffic scenarios and recommend potential design modifications to ensure NASA's QoS requirements are met

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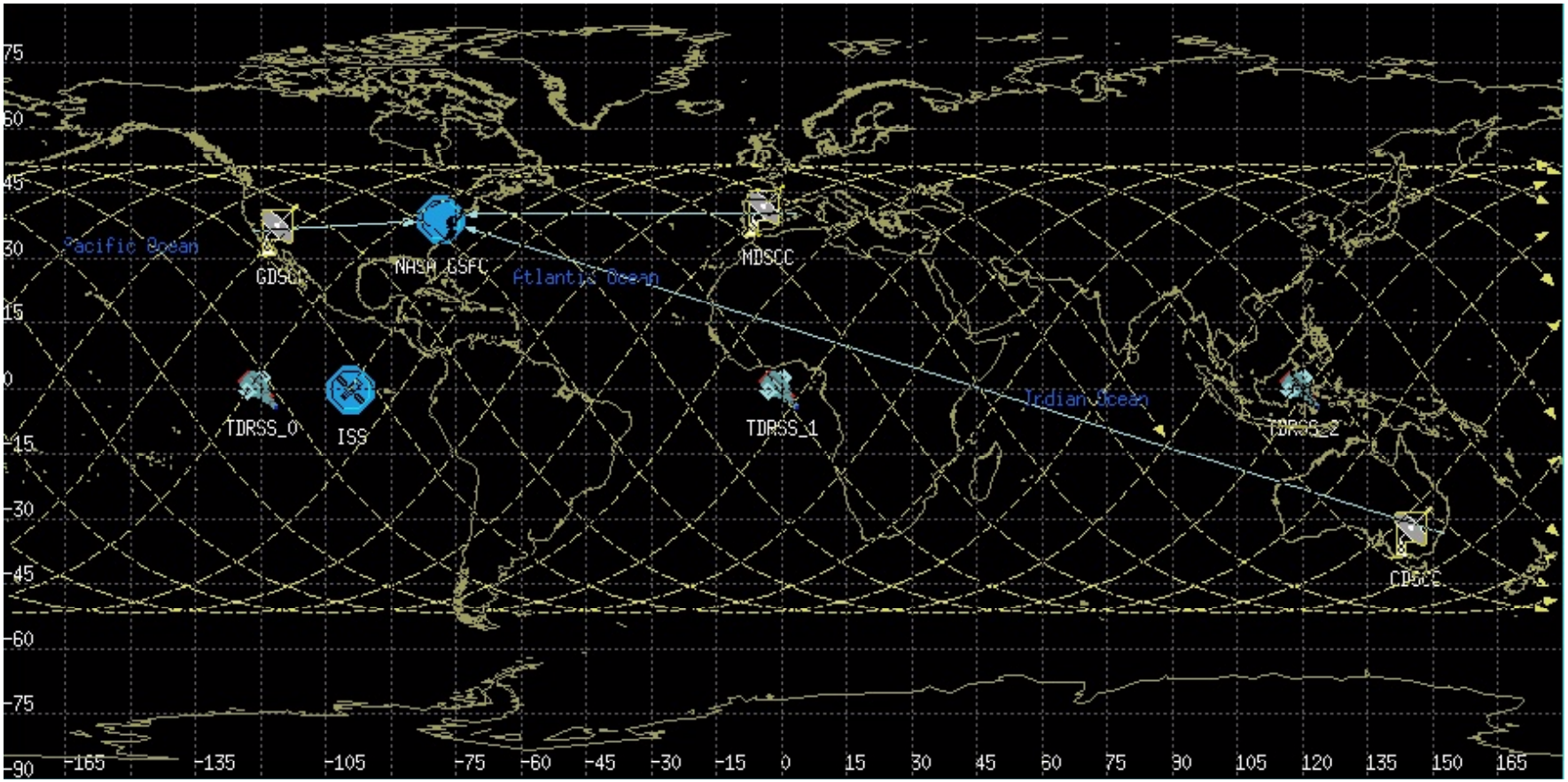
Performance Parameters for NASA Missions

- **Performance parameters that need to be addressed include:**
  - COVERAGE : Percent of time that data could be transmitted to the ISS via the commercial satellite system (this includes Static & Dynamic coverage and the effect of Inter Satellite Links)
  - THROUGHPUT : Maximum amount of information that can be exchanged between constellation & ISS, based on service availability and the per channel data rate
  - QUALITY-OF-SERVICE : Level of confidence for the reliable delivery of information to NASA users: Link quality (BER), Link Availability, Connectivity
  - ANTENNAS & TERMINALS : Antenna & earth terminal characteristics wrt required link quality. It would be necessary to have an antenna design well suited for covering both LEO vehicles and terrestrial traffic

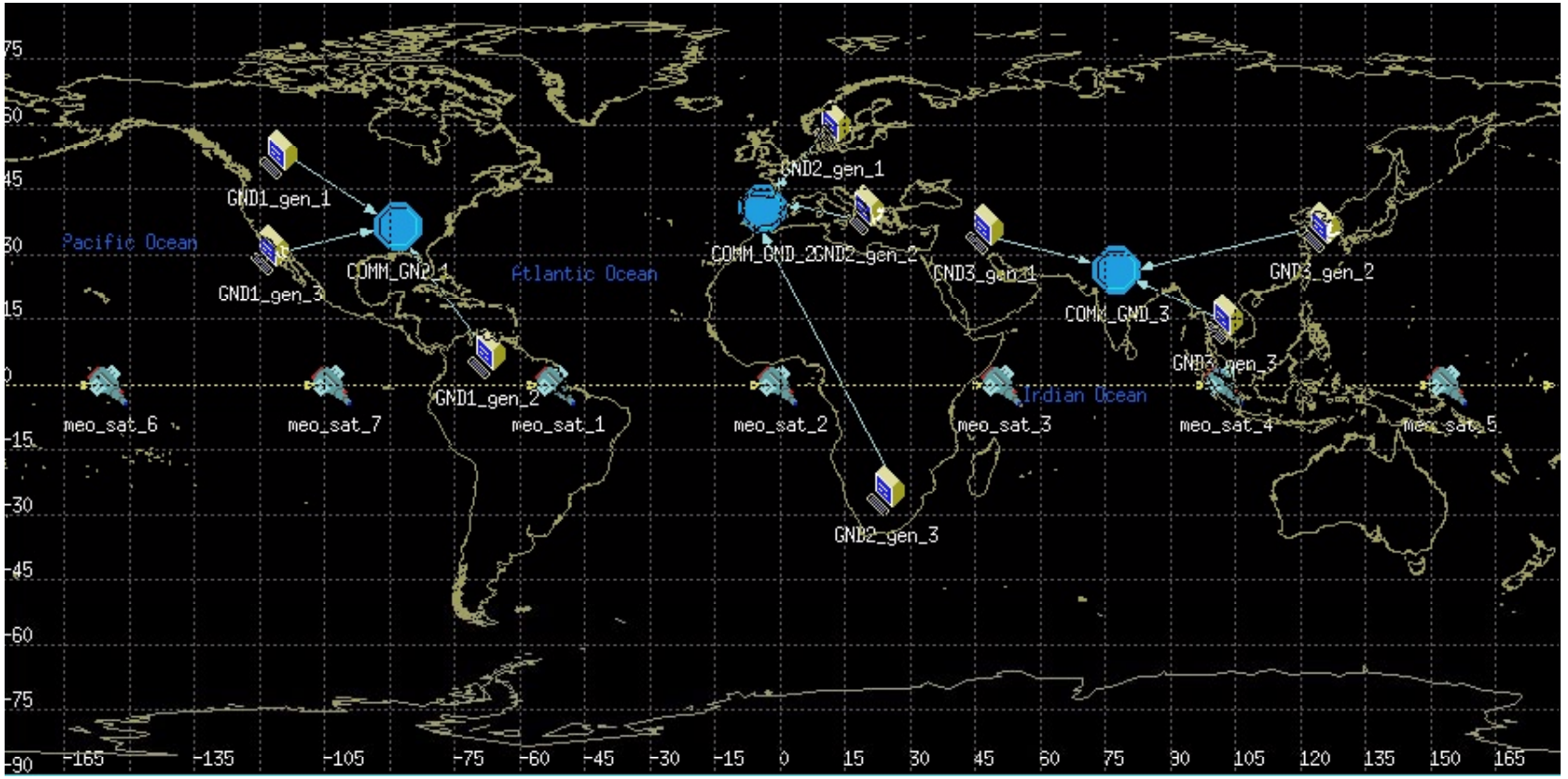
Accomplishments - Broadband Support for NASA Missions

Completed generic simulation model consisting of the ISS with a network of three ground stations and three GEO satellites, representing a network architecture similar to NASA's TDRSS-DSN.



Accomplishments - Broadband Support for NASA Missions

Developed second model that consists of a commercial network of 7 satellites in MEO orbit (9000 km), and commercial ground stations. Each station is connected to three other commercial network gateways. Satellite network performs basic shortest-path hop-by-hop routing based on destination ID using established inter-satellite links.



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Continuing Work

- **It will be *critical* at an early stage to understand the operations requirements for telescience that will need to be supported. This will enable us to**
  - model traffic loads and QoS requirements,
  - evaluate candidate constellations on their ability to support these services
  - optimize the system's performance.
  - Plan bandwidth requirements with future use in mind.

Work is under way to determine these / provide reasonable assumptions.

- **Modeling & investigation work continues in three directions:**
  - Development of flexible generic model that can be used with suitable adjustments to simulate various traffic and constellation scenarios.
  - Investigation into protocol support required under this scenario (including TCP/IP, NASA's SCPS, SAFE)
  - Extension of this work to other NASA missions, constellation of scientific satellites, issues related with treating spacecraft or instruments on-board as nodes of a network (Interest from NASA Goddard, Lewis RC)